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CAVES AND KARST SITES OF POLAND AS A CONTRIBUTION TO GEOLOGICAL HERITAGE OF CENTRAL EUROPE

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Abstract. Evaluation of caves and karst sites as geological heritage should regard three aspects related to function of these objects and their perception: a) caves as shrouded in mystery "gates to underground" (anthropocentric approach); b) caves as places of unique minerals and rocks formation (natural approach); c) karst sites and caves as witnesses of geological past (scientific approach). Regarding these aspects as criteria of evaluation, 25 objects of super regional value have been selected. Majority of them represent important scientific sites. Studies of the sites enable reconstruction of palaeoenvironment (climate) and fauna in Cenozoic, especially Younger Pleistocene in the Polish uplands, as well as reconstruction of geological evolution of the Holy Cross Mts. and the Cracow region after Variscan tectonical movements (Permian, Triassic, Jurassic). Majority of the sites are legally protected, but four are located in active quarries and mines, in danger of destruction.

Key words: caves, karst sites, network of European geosites, Poland.

Abstrakt. Waloryzacja jaskiń i innych stanowisk krasowych, jako dziedzictwa geologicznego, powinna uwzględniać trzy aspekty wynikające z roli tych obiektów i sposobu ich percepcji przez człowieka: a) jaskinie jako „bramy podziemnego świata", fascynujące tajemniczością i odmiennością (podejście antropocentryczne); b) jaskinie, jako miejsce powstawania specyficznych form mineralnych i skalnych (podejście przyrodnicze); c) stanowiska krasowe i jaskinie, jako świadectwa przeszłości geologicznej (podejście naukowe). Traktując te aspekty jako kryteria waloryzacji wybrano 25 stanowisk o wartościach ponadregionalnych, które w większości mają znaczenie badawcze. Ich badania dostarczają istotnych informacji o przemianach środowiska (klimatu) i świata zwierzęcego w kenozoiku, zwłaszcza w młodszym plejstocenie na terenie wyżyn polskich, jak również o ewolucji geologicznej regionu świętokrzyskiego i krakowskiego w okresie po ruchach waryscyjskich (perm, trias, jura). Większość stanowisk jest objęta ochroną prawną, jednak cztery znajdują się na terenie czynnych kamieniołomów i kopalń podziemnych, co zagraża ich istnieniu.

Słowa kluczowe: jaskinie, stanowiska krasowe, sieć europejskich geostanowisk, Polska.

INTRODUCTION

Several aspects should be taken into account in evaluation of caves and karst sites as elements of natural heritage. The most popular, anthropocentric approach to caves is based on subjective human aesthetic sense and cultural traditions and manifested by tourist activity in caves. It regards caves as "gates to underground" — mysterious places often hardly accessible for man (although their near-entrance parts were inhabited by people for thousands years), with picturesque, fascinating forms (speleothems, corrosion cavities of unique shape). Two other aspects are referred to natural and scientific values of caves and karst objects.

According to one of them, caves represent spaces characterised by specific environment, necessary for existence of unique fauna and flora assemblages (which are not a subject of this paper), as well as development of unique mineral aggregates, rocks and denudation forms ("natural" approach with scientific consequences). The second aspect is focussed on karst forms as unique objects formed in terrestrial periods of geological history, which

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— confined to "host rocks" of substratum — are often preserved, unlike other denudation forms.

Therefore, caves, sinkholes, potholes, karst fissures, etc. constitute specific "traps" in which records of geomorphological events and environmental changes are conserved and accessible for research works. In many cases, the karst forms were strictly traps for fauna, becoming prominent palaeontological localities. In consequence, karst forms play significant role in recognition of geological evolution of Earth surface in periods which are not documented by sequences of sedimentary rocks accumulated in basins (Głazek, 1973; Bosak, 1995; Urban *et al*., 1997). It should be emphasised the great importance of research works in caves for reconstruction of palaeoclimate, fauna assemblages and human activity in the Late Pleistocene (e.g. Hercman, 2000; Madeyska, Cyrek, 2002). Furthermore, studies of non-karst caves give important data on some other processes which shaped the Earth surface: erosional, gravitational, volcanical, etc. (Urban, Otęska-Budzyn, 1998; Gradziński, Jach, 2001).

The fourth approach emphasises environmental character of karst system, regarding it as an unit of geosphere (geotop), which interacts with others elements, also with human activity (Bella, 1995). Practically, karst systems are often used as underground water reservoirs. Caves are also a subject of economical activity of tourist agencies (managing public access) or industrial works (as fragments of mines, etc.).

SCIENTIFIC IMPORTANCE AND OTHER VALUES OF CAVES AND KARST SITES OF POLAND

Short description of caves and karst sites of super regional importance in Poland is given in Appendix 1. These objects usually represent more than one evaluation aspect mentioned above (e.g. Raj cave with hundreds of stalactites is also an important palaeontological and archaeological locality) and diversity of geological and geomorphological phenomena (Fig. 1). Scientific importance is a fundamental criterion of super regional value of majority of sites (Fig. 2). The caves and karst objects were formed mainly during the long terrestrial periods following the last two main stages of tectonical movements: Variscan and Alpine, although relics of depositional karst, developed during short breaks in sedimentation of Devonian and Carboniferous carbonates, have been described, too (Fig. 1).

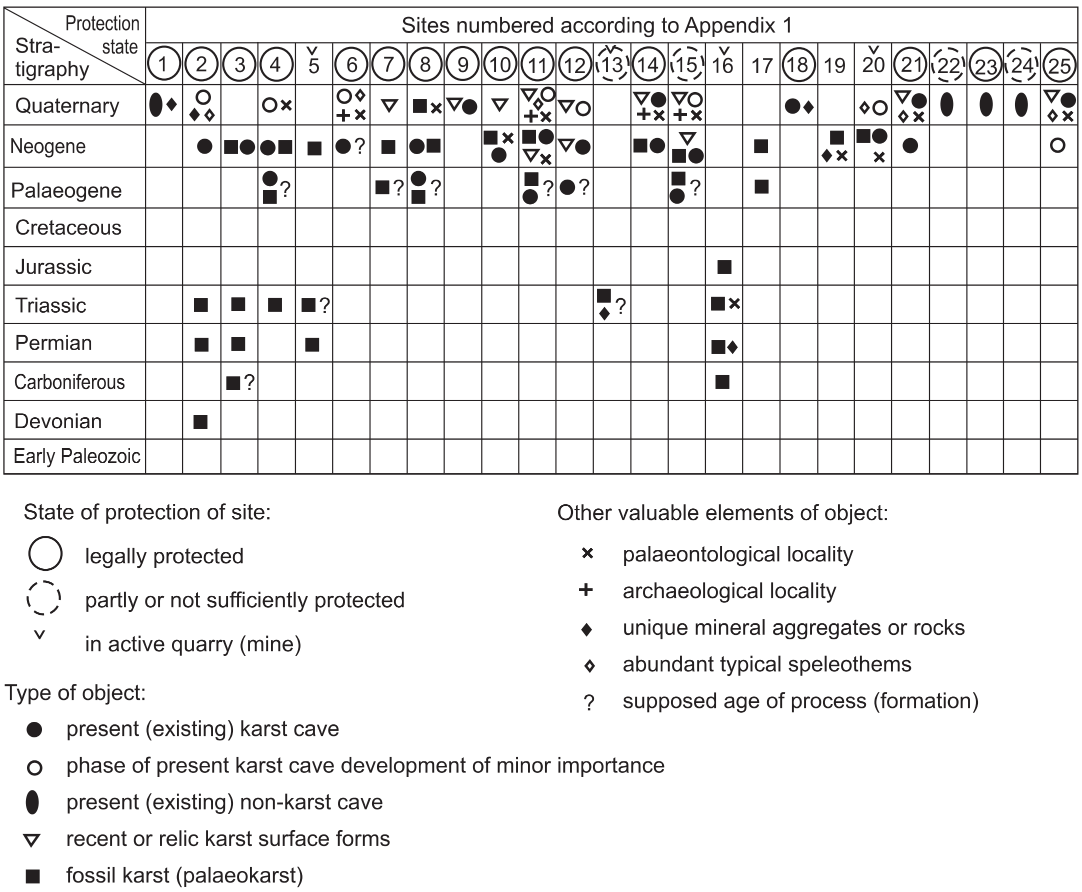

Fig. 1. Types and features of the most important caves and karst sites in Poland and their age (stratigraphy)

Numbers consistent with Appendix 1

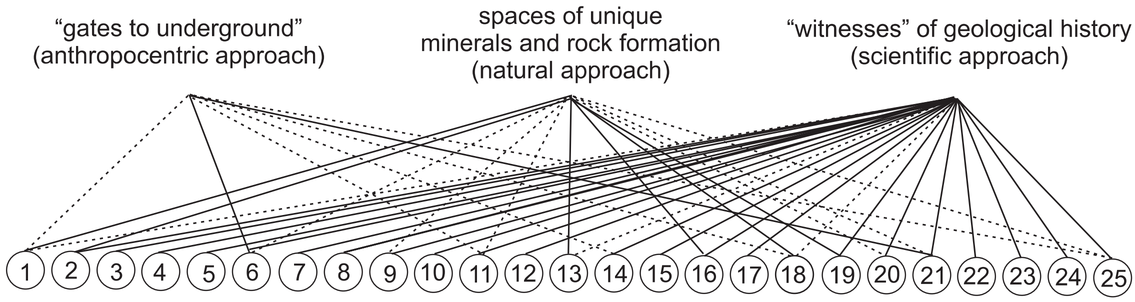

Fig. 2. Main criteria of caves and karst sites evaluation (rectangles) referred to these objects in Poland

Circles with numbers consistent with Appendix 1; full line — fundamental value, dashed line — value of minor range

Karst sites of the first, epi-Variscan cycle, located in the Holy Cross Mts. (Fig. 3) — Wietrznia, Jaworznia and Kowala — represent almost the only objects documenting phases of morphological evolution of the region, as well as deep and shallow water circulation, which were controlled by tectonical events during Permian and Lower Triassic. Studies of these sites confirm similarities between the Holy Cross Mts. region (situated outside the Variscan orogenic belt) and strictly Variscan mountains, during main phases of tectonical movements and post-orogenic evolution (Urban, 2002, 2004). Sites in the Holy Cross Mts. are not documented by palaeontological evidences, whereas the karst site in Czatkowice near Kraków (Cracow) represent important palaeontological locality, suitable for studies of Lower Triassic vertebrates. Several karst generations in the Czatkowice quarry document denudation phases related to Late Variscan and Early Alpine movements (Paszkowski, 2000).

Cenozoic karst sites located in Central and Southern Poland (Fig. 3), especially in the Cracow–Wieluń Upland, also in the Sudetes Mts. and the Holy Cross Mts., represent almost the only palaeontological sites of Middle Miocene or Pliocene-Pleistocene fauna (with an exception of Upper Pleistocene fauna, often found also in non-karst localities), mainly vertebrate bones. In younger, Upper Pleistocene sites important archaeological artefacts are often found, too. Owing to palaeontological and geological studies of deposits, in these sites palaeogeographical and palaeoenvironmental (palaeoclimatic) reconstruction of super regional importance have been presented. Lack of sites of Upper Miocene fossils in Central Poland is the main argument suggesting large marine transgression at this time, whereas occurrence of Middle Pleistocene fauna representing relatively warm climate in Kozi Grzbiet site allowed to distinguish interglacial period (Głazek, Szynkiewicz, 1987; Głazek, 1989; Lindner, 1991).

Other trend of scientific studies of palaeontological sites is represented by numerous monographs of faunistic groups (not quoted here because of great number of positions), among others, unique groups of fossils, e.g. beetles in Przeworno. Except for mentioned above, important palaeontological-archaeological sites are represented by caves in Ojców National Park (NP) and Ojców Plateau, Jaskinia Niedźwiedzia, Raj, Węże and Kadzielnia (Studies..., 1972; Głazek *et al*., 1976, 1977; Głazek, 1989; Jahn *et al*., 1989; Madeyska 2000). Some sites have been not sufficiently investigated yet (e.g. Sokole Góry, Góra Zborów and Połom).

In some sites (areas), observations of spatial position and morphology of karst forms as well as lithological studies of their infilling led (or can lead) to important palaeogeographical conclusions. The most interesting examples of Cenozoic karst systems are represented by Ojców NP, Ojców Plateau, Sokole Góry, Góra Zborów and Zabierzów in the Cracow-Wieluń Upland, Kadzielnia, Jaworznia, Zelejowa Góra and Miedzianka in the Holy Cross Mts., Skorocice in the Nida Basin, Połom in the Sudetes Mts., as well as the Tatra Mts. in the Inner Carpathians (Kozłowski *et al*., 1965; Madeyska, 1977, 1981, 2000; Głazek,

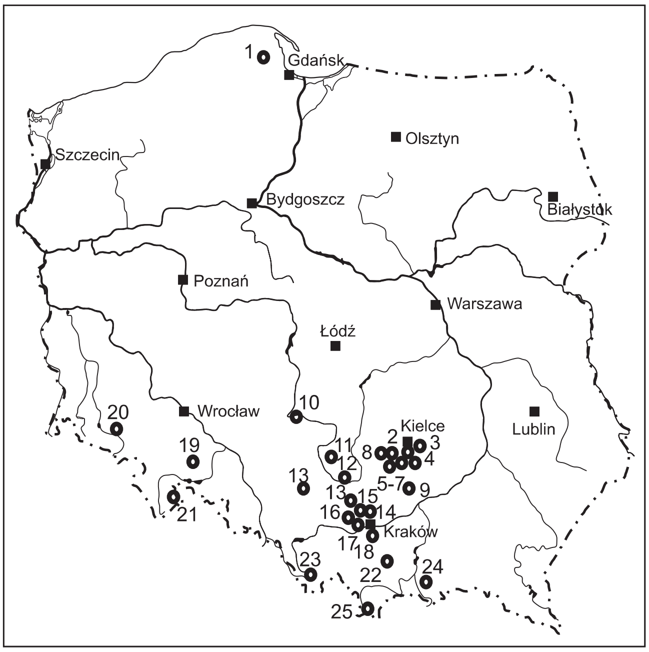

Fig. 3. Location of the most important caves and karst sites in Poland

Numbers consistent with Appendix 1

1989, 1996; Gradziński, 1999; Felisiak, 2000; Madeyska, Cyrek, 2002; Urban, 2002; Urban *et al*., 2002; Urban *et al*., 2003; Rogala, 2003). These studies are often extended recently by U-series and radiocarbon dating as well as stable isotopic analyses of speleothems, what enables determination of age of forms, phases of caves development and palaeoenvironment (Hercman, 1991, 2000).

Studies of non-karst caves, which are very frequent in the Outer, Flysch Carpathians and genetically related to gravitational mass movements, give an opportunity for reconstruction of landslides' formation phases. The most instructive and illustrative caves (cave groups), which were thoroughly studied, are: Jaskinia Malinowska and caves in Łopień Mt. and Wierch Mt. nad Kamieniem (Margielewski, Urban, 2002, 2003).

Six caves represent places of unique minerals, rock or forms occurrences (Fig. 2, 3). The most exceptional among them are Groty Kryształowe (Crystal Caves) in Wieliczka Salt Mine, formed 80 m below surface and lined by large halite crystal covers, as well as Jaskinia w Mechowie, developed in Pleistocene sandstones (Alexandrowicz Z., 2000; Urban, 2000). Unique are also Late Pleistocene calcite crystals found in Chelosiowa Jama-Jaskinia Jaworznicka cave in Jaworznia (Žak *et al*., in print), as well as chalcedonite speleothems occurring in Czatkowice and Przeworno (Głazek *et al*., 1977; Paszkowski, 2000). Specific karst sediments represent also Pb–Zn ores, forming MV type deposits in Silesia–Cracow region, represented by Olkusz and Tarnowskie Góry mines (Sass-Gustkiewicz *et al*., 1982).

The anthropocentric criterion of evaluation is of great importance for two objects only (Jaskinia Niedźwiedzia and Raj caves); for some other it is of minor significance (Fig. 2). It means that only a few Polish caves are comparable with famous tourist caves of Europe.

PROBLEMS OF LEGAL AND PRACTICAL CONSERVATION

Not all sites mentioned above are protected by law. Among the seven not protected, four (Kowala-Wola, Olkusz, Czatkowice and Połom) are located in active quarries or mines, in danger of total destruction because of economical reasons, as it happened with prominent karst site of Middle Triassic vertebratas in Stare Gliny (Głazek, 1973, 1989), discovered about 1960 and quarried out soon. Some legally protected object were degraded or almost totally damaged by quarrying/mining in the past, scientific excavation or fossils/minerals collecting. To the most devastated sites belong: Węże, some caves in Ojców NP and Ojców Plateau, Sokole Góry, Kozi Grzbiet and Przeworno.

Legal protection seems to be necessary but not sufficient condition for geological site conservation, which requires some additional activities. Between practical conservation of caves and conservation of fossil karst (palaeokarst) sites, are fundamental differences because caves represent completely underground forms with one or more entrances, whereas fossil karst sites constitute almost exclusively artificial outcrops in quarries or mines.

In a case of caves which represent unique and vulnerable "integrity sites" (Daly *et al*., 1991), subjects for protection are not only rocks and relief but the whole cave environment, as well. The main external and internal threats are caused by human impact, and practically no method of protection is fully efficient (Cave conservation..., 1995; Urban *et al*., 1997). Thus the protection is practically carried out by: 1) control and arrangement of peoples access to caves (Jaskinia Niedźwiedzia, Raj, several caves in the Ojców NP, Ojców Plateau and Tatra Mts, to some extent also Sokole Góry and Groty Kryształowe), which should be often restricted or 2) by closure of caves. This first method gives imperfect results, whereas the second one is controversial (because of limited cave ventilation causing changes of internal environment and fauna, e.g. bats) and effective only, if the locks of cave entrances are almost permanently under control (e.g. Chelosiowa Jama-Jaskinia Jaworznicka cave in Jaworznia, Jaskinia Maurycego cave in Sokole Góry). Also explorations and researches in the caves should be limited and supervised in order to protect the scientific materials (Cave conservation..., 1995; Urban *et al*., 1997; Urban *et al*., 2002).

Practical preservation of artificial outcrops in open-pits is conditioned by many factors, predominantly by type of "host rocks" and sediments filling karst forms, as well as local land management. Lithology of rocks determines type of derivative processes shaping the rock surface as well as rate of soil and plant cover development. In a case of Cenozoic karst forms, sediments are often poorly lithified, soft and loose, what result in very fast process of outcrops deterioration (Szynkiewicz, 1977). Several karst sites of super regional importance (mentioned above) are hardly accessible now because of complete or partial plant covering. Some technical methods are proposed for protection of artificial outcrops (e.g. McKirdy, 1994). All of them require vigorous human activity managed by public (central or local) administration of nature conservation.

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Appendix 1

List of the most important karst sites and caves in Polish regions

Polish Lowlands: area formed of thick cover of Quaternary, mainly glacial and fluvioglacial sediments.

<u>1. Jaskinia w Mechowie cave</u> (nature monument) — cave in Pleistocene sandstones (sands cemented with calcite), 61 m long and partly artificially extended; in the entrance natural, picturesque sandstone colonnade reflecting the columnar-type cementation; site has been protected almost since discovering in 1818; it is accessible for public now (Urban, 2000).

Mid-Małopolska Upland (Holy Cross Mts., Nida Basin): uplands formed of Palaeozoic–Mesozoic–Tertiary sedimentary rocks; more than 250 mainly karst caves.

<u>2. Jaworznia quarry and Chelosiowa Jama–Jaskinia Jaworznicka cave</u> (nature reserve) — remnants of multiphase karst in Upper Devonian limestones cropped out in abandoned quarry (Urban, 2002): a) Devonian, depositional karst (Skompski, Szulczewski, 2000), b) Permian–Lower Triassic (epi-Variscan) surface and subsurface karst forms, covered or filled with sediments, among them wide and low channels developed probably in mixing zone of fresh and sea waters (Głazek, 1989; Urban, in print), c) maze, horizontal system of Cenozoic (predominantly Tertiary) mainly phreatic karst passages, which often superimpose older karst and were developed mainly due to diffusion mixing of different fresh waters — the longest Polish cave (3670 m) outside of the Tatra Mts. (Urban *et al*., 1997); unique calcite forms (Żak *et al*., in print).

<u>3. Wietrznia</u> (nature reserve) — abandoned quarry of Devonian carbonates with evidences of 3–4 phases of Permian–Early Triassic (epi-Variscan) denudation, mainly karstification; fossil karst forms — large doline, sinkholes and subsurface conduits — are filled with breccia, bedded limestones, marls, claystones and siltstones with sandstone inserts; in the sequence of these deposits transition from Permian to Buntsandstein types of sedimentation is documented; also Cenozoic karst forms (Urban, 2002, in print).

4. Kadzielnia (nature reserve) — abandoned quarry of Devonian limestones strongly karstified; the karst is represented by large potholes filled with varicoloured clays, loams and sands, and some 25 caves of various spatial (vertical) position; the forms belong to several generations of Cenozoic karst; similarity of some karst infilling of Permian–Triassic rocks (due to re-deposition) caused fervent discussion on the karst age in the past; fossils of Pliocene–Early Quaternary vertebrata (Kozłowski *et al*., 1965; Urban, 2002).

5. Kowala–Wola (Nowiny) — active quarry of Devonian limestones and marls; in the limestones occur Permian (epi-Variscan) crevices with traces of karstification on the walls; the crevices (veins) are filled with hydrothermal druse calcite, marls, claystones and clastics, which prove inflows of thermal, deeply circulating and cold, meteoric waters (Urban, 2002, 2004).

6. Raj Cave (nature reserve) — horizontal cave in Devonian limestones, 240 m long and accessible for public; abundant with speleothems represented by hundreds of straw stalactites, other types of dripstones, flowstones (draperies) and pisoids; in the clayey-clastic deposits — Late Pleistocene fauna typical for cool climate of last glaciation as well as Palaeolithic (Charentian) culture horizons (Studies..., 1972).

7. Zelejowa Góra (nature reserve) — hill formed of Devonian limestones with remnants of Early Triassic karst, following in places hydrothermal calcite veins and often superimposed by Tertiary karst forms: sinkholes and crevices filled with sands and loams representing redeposited Triassic sediments; interesting recent karst manifested by karrens (lapiez) developed on rocky hill ridge (Rzepa, 1974; Urban 2002).

8. Miedzianka and Kozi Grzbiet (nature reserve and nature monument) — two hills formed of Devonian limestones: Miedzianka — numerous underground karst forms filled with redeposited Triassic sediments (red clays) containing minerals of weathering zone of copper ore deposit; uppermost conduits represent one of the oldest Cenozoic karst phase of the Holy Cross Mts. region (Palaeogene, Lower Miocene?) (Rubinowski, 1971; Urban, 2002); Kozi Grzbiet — in abandoned quarry karst form (shaft) filled with clays, loams and sands containing numerous fossils, mainly bones of small vertebrates; study of the fossils enabled definition of interglacial period in the Middle Pleistocene (Głazek *et al*., 1976a; Lindner, 1991).

9. Skorocice valley (nature reserve) — karst valley formed in Miocene gypsum rocks during Late Quaternary and still developing, the most representative for karst in gypsum of Poland; two segments of the valley — blind, upper part and lower part — are connected by subsurface conduit with water stream (the longest cave in gypsum of Poland — 352 m long); within the valley hums and sinkholes, as well as more than 25 other caves consisting mainly of horizontal chambers and passages (Flis, 1954; Urban *et al*., 2003).

Silesian-Cracow Upland: uplands formed of Palaeozoic (mainly Carboniferous) and Triassic rocks (SW part) and Upper Jurassic limestones (NE part — Cracow–Wieluń Upland), in NE part up to 1000 mainly karst caves have been listed.

10. Węże (Zelce) (nature reserve) — hill formed of Upper Jurassic limestone with numerous short caves representing remnants of Tertiary underground karst system; in cave sediments (calcareous flowstones with sand and rubble admixture) numerous Late Pliocene fossils, mainly bones of large mammals have been discovered; two known palaeontological sites are almost totally excavated and recent studies are carried mainly on collections (Głazek *et al*., 1976b; Głazek, Szynkiewicz, 1987; Stefaniak, 1995).

11. Sokole Góry (nature reserve) — group of hills formed of Upper Jurassic limestones with Tertiary and Quaternary surface karst microforms and more than 90 caves representing several types: a) 6 caves longer than 100 m and up to 80 m deep, belonging to the longest and deepest in the region, b) shorter karst passages — remnants of fossil karst systems, c) karst cavities filled with speleothems, widened due to historical calcite excavation, d) pseudokarst, gravitational caves; karst caves represent Tertiary phases of karstification, simultaneous with initial stages of relief development (Skalski, Wójcik, 1968; Szelerewicz, Górny, 1986; Tyc, 2001; Urban *et al.*, 2002); fossils of Tertiary and Late Pleistocene fauna, archaeological artefacts (Horáček, Hanák, 1983–1984; Gierliński *et al*., 1998).

12. Góra Zborów (Podlesice) (nature reserve) — hill dominating above surrounding areas, formed of Jurassic limestone, with numerous crags, rocky walls on the slopes and surface karst forms: collapse dolines and labirynths of passages (elongated dolines, bogazes) as well as microrelief (karrens, kamenitzas etc.); more than 15 caves (from several to more than 100 m long) (Szelerewicz, Górny, 1986; Tyc, 2001).

13. Mines of Olkusz or Tarnowskie Góry — in the both sites hydrothermal karst forms developed mainly in Middle Triassic secondary dolomites; phreatic karst, formed probably during Late Triassic in confined aquifer due to deep water circulation and related to Pb–Zn ores deposition; several cycles of karstification, breakdowns and mineralisation were distinguished (Sass-Gustkiewicz, 1975; Sass-Gustkiewicz *et al*., 1982); in the active Olkusz mine typical karst forms were described, whereas abandoned Tarnowskie Góry mine — now museum — is preserved and accessible for public.

14. Valleys of Prądnik creek and its tributaries (Ojców National Park) — valleys (gorges) deeply incised in the upland formed of Upper Jurassic limestones; numerous crags and rocky walls on the slopes, as well as caves of several tens to several hundreds meters long; spatial position of the caves indicates phases of relief development in Late Tertiary and Quaternary; in younger Pleistocene sediments — loams with sands and limestone rubble — numerous fossils, mainly bones, as well as remnants of Palaeolithic human cultures have been thoroughly studied (Chmielewski, 1975, 1988; Madeyska, 1977, 1981, 2000; Szelerewicz, Górny, 1986; Alexandrowicz S.W., Alexandrowicz Z., 1999; Madeyska, Cyrek, 2002); part of the area and several caves are accessible for public.

15. Ojców Plateau near Jerzmanowice (some nature monuments in landscape park) — plateau fragmented by some valleys, formed of Upper Jurassic limestones, with rocky monadnocks and caves of up to several hundreds meters long; the relief was developing during Tertiary (Alexandrowicz S.W., Alexandrowicz Z., 2003); in the caves remnants of Tertiary (Palaeogene–Miocene, Gradziński 1999) deposits have been found, but Quaternary loams with sands and limestone rubble predominate; in some caves Late Pleistocene fossils, mainly bones as well as archaeological materials have been thoroughly studied (Chmielewski, 1975; Madeyska, 1981, 2000; Szelerewicz, Górny, 1986; Madeyska, Cyrek, 2002).

16. Czatkowice — active quarry of Lower Carboniferous limestones with karst forms representing several generations (Paszkowski, Wieczorek, 1982; Paszkowski, 2000): a) Early Carboniferous, depositional karst, b) Early Permian large karst forms filled with tuffites and various carbonates and siliceous deposits, c) Early Triassic potholes filled with sandy-silty deposits with calcite and gypsum inserts and aggregates; underground forms filled with similar infilling containing fossils of small vertebrata: amphibian, reptiles and fishes (Borsuk-Białynicka *et al*., 1999; Borsuk-Białynicka *et al*., 2003); d) Early Jurassic cave filled with sandy-silty sediments cemented with calcite.

17. Zabierzów — fossil karst forms: sinkholes and subsurface conduits, cropped out in abandoned quarries of strongly faulted Upper Jurassic limestones and Upper Cretaceous limestones and marls; karst forms represent early phase of Cenozoic karstification (Oligocene–Early Miocene), what is documented by lithological composition of their infilling: mainly clays with sands and rubble of local material (Felisiak, 1992, 2000).

Carpathian Foredeep: flat area formed of Miocene molasse: claystones, siltstones, locally sandstones.

18. Groty Kryształowe (Crystal Caves) in Wieliczka Salt Mine (nature reserve) — two chambers in Middle Miocene salt-bearing claystones, siltstones and sands, situated 80 m under the surface and discovered during salt mining at the end of XIX century; the cavities are natural, formed by karstic dissolution or by tectonical processes, in part artificially widened (the upper chamber); despite of anthropogenic changes large fragments of natural walls are covered by halite crystals (with edges up to 34 cm long); the crystalline covers were formed during cold periods of Pleistocene (Alexandrowicz Z., 2000).

Sudetes Mts.: mountains and hilly uplands formed of variety of magmatic, metamorphic and sedimentary rocks, more than 100 karst and pseudokarst caves have been listed.

19. Przeworno — abandoned quarry of Proterozoic marbles with three Cenozoic karst objects: a) subsurface conduit filled with clays containing bones of Early-Middle Miocene fauna, b) surface karst form filled with clays, rubble and blocks, in which remains of Middle Miocene fauna have been found, c) cave filled with clays and siliceous speleothems related probably to thermal springs; in the siliceous flowstones unique fossils of Middle Miocene beetles have been studied (Głazek *et al*., 1977; Głazek, 1989); the site is poorly accessible now: partly under water level, partly covered by debris, soil and plants, in part completely excavated.

20. Połom (Wojcieszów) — karst in a large lens of Cambrian marbles, cropped out in abandoned and active quarries on mount slopes; it is represented by more than 35 caves of total length up to 3000 m and large surface forms filled with sediments; karst passages are featured by different, changing directions and inclinations suggesting at least partly lithological controlling their development; in the sediments (gravels, sands and loams) remnants of Pliocene fauna were found (Rogala, 2003); active quarrying resulted in destruction of some caves.

21. Jaskinia Niedźwiedzia (nature reserve) — cave formed in a large lens of Lower Palaeozoic or Proterozoic marbles in the slope of Kleśnica stream valley; the cave is 2230 m long and composed of three levels, related to stages of valley development; in chambers and passages of the middle level, large and picturesque speleothems of various shape occur, mainly calcite dripstones, flowstones and pisoids; in cave sediments — sandy-silty gravels and rubbles — numerous fossils of Late Pleistocene fauna, predominantly bones of large mammals have been found (Jahn *et al*., 1989; Jahn *et al*., 1997).

Outer Carpathians (Beskidy Mts.): mountains formed of Cretaceous and Palaeogene flysch (bedded sandstones with shales), more than 600 pseudokarst caves have been found.

22. Łopień (nature monument) — more than 10 typical pseudokarst caves in the Outer Carpathians; the caves have developed due to gravitational movements of the mount slope (landslides) and represent two types: talus type — situated in the block-colluvium of landslide (Grota Zbójnicka, 404 m long maze network of crevices and chambers), and crevice type — located in the upper part of the landslide, near the head-scarp (e.g. 105 m long Złotopieńska Dziura cave, consisting of four levels of passages); study in the caves enables interpretation of gravitational mass movements of slope (Margielewski, Urban, 2002, 2003).

23. Malinowska cave (nature monument) — pseudokarst, crevice type cave located in the mount slope without landslide, what indicate that its formation preceded landslide development, the cave was thoroughly studied in order to reconstruction initial stages of gravitational slope evolution (Margielewski, Urban, 2002, 2003).

24. Wierch nad Kamieniem — several pseudokarst, crevice type caves located in different position in relation to the large landslide: a) in slightly loosen mass of the slope above the landslide, b) near the main scarp, c) in large rock packet within colluvial swell of the landslide; one of the longest pseudokarst caves in Poland — Jaskinia Niedźwiedzia, 611 m (Margielewski, 1997; Pulina, 1997).

Inner Carpathians – Tatra Mts.: high mountains with Alpine type relief; very complex geological structure: magmatic-metamorphic core surrounded by cover formed of sedimentary, mainly carbonate rocks.

25. Tatra Mts. (Tatra National Park) — more than 600 mainly karst caves developed since the Pliocene, many different types of forms: high-mountainous (sub)vertical vadose conduits, branchwork patterns of nearly horizontal passages often forming systems composed of several levels, complex systems of phreatic origin (remnants of artesian or thermal water flows), short passages related to glaciations, etc.; the longest and deepest caves of Poland — Wielka Śnieżna–Wielka Litworowa 22 km long, 816 m deep; in some caves Pleistocene fossils; surface karst forms typical for particular climatic zones of high mountains (Rudnicki, 1967; Wójcik, 1968; Hercman, 1991, 2000; Głazek, 1996; Głazek, Grodzicki, 1996).